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ELECTRONICS AND ELECTRICAL ENGINEERING

No. 76

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USSR REPORT  
ELECTRONICS AND ELECTRICAL ENGINEERING

No. 76

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## AMPLIFIERS

UDC 621.318.43:681.3

### THE APPLICATION OF A REGRESSION TECHNIQUE TO THE REJECTION OF PERMALLOY CORES

Novocherkassk IZV. VUZ: ELEKTROMEKHANIKA in Russian No 8, Aug; 80 pp 879-882 manuscript received 3 May 79

BEZRUKOVA, V. L., engineer, "Start" Special Design Office, VARSHAVSKIY, L. G., senior engineer of the Special Administration of the Special Design Office, ZHUKOVSKIY, Yu. G., candidate of technical sciences and senior scientific research worker of the Special Administration of the Special Design Office, and KHANZHIVYEV, A. S., chief of the "Start" Laboratory of the Special Design Office, all at Novocherkassk Polytechnical Institute

[Abstract] A regression analysis of magnetic amplifiers is proposed for the prediction of the conformity of the electrical characteristics of these amplifiers to the technical specifications prior to their assembly. The following core parameters are taken as the initial parameters of the model: the coercivity,  $H_0$ , and the maximum induction at a field intensity of about  $5H_0$ . These parameters are easily checked with an oscilloscope and have a substantial impact on the output response of a magnetic amplifier. The following assumptions underlie the application of the regression technique: 1) The experimentally obtained values of the output voltages of the amplifiers are independent normally distributed random quantities; 2) When a number of repeated tests are made on cores for specified values of the maximum induction and the coercivity, the dispersions of the output voltage do not depend on the mean value of the voltage, i.e., do not differ from the dispersion obtained by a repeated experiment for any other set of coercivity and induction values; and 3) In the testing of the amplifiers, there are no factors which lead to a drift in the parameters of the cores or a degradation in the precision of their measurement. The output response is modeled by digitization of the response in a series of points; the regression models for the instantaneous output voltages as a function of the coercivity and maximum induction is computed by the "Model" program, written in ALGOL-60 for the M-222 computer. The program estimates the regression coefficients by the method of least squares, as well as the precision of the resulting estimates, their significance and the significance of the entire regression equation as a whole. A "Razbrakovka" ["Rejection"] program was also compiled in the same language for the M-222; this routine plots the predicted response of the magnetic amplifier and superimposes it in the region of permissible values. In the case of good agreement, the number of the core and the "Good" indicator is printed out. The operation of these programs is illustrated with specific magnetic amplifier cores and the range of permissible parameters are plotted graphically. These two regression analysis programs are sufficient for the quality control rejection of cores prior to final assembly. Figures 3; references: 5 Russian.  
[26-8225]



## SPECIFIC FEATURES OF THE AMPLITUDE AND FREQUENCY CHARACTERISTICS OF AMPLIFIERS WITH ADAPTIVE PULSE-WIDTH MODULATION

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 89-91 manuscript received 16 Jul 79

ALEKSANYAN, A. A. and GALAKHOV, V. A.

[Abstract] The use of adaptive pulse-width modulation circumvents the problems of linear and nonlinear distortions in switched, high power low frequency amplifiers. Previous approximation methods developed in order to describe the processes in this class of amplifiers using low pass filters with complex (RLC) networks do not adequately account for the transient response of such amplifiers. This paper briefly describes the results of calculations for the case where the amplifier circuit uses an LC second order low-pass filter with a maximally flat response. The switching period and the output voltage period as a function of the relative signal level at the amplifier input are found to be in rather good agreement (2-10%) with the results of approximate calculations. The computations show that the moments of step changes in the phase correspond to the points in time when the number of pulses at the input to the low-pass filter changes during the half-periods of the frequency being amplified. The results were checked with a breadboarded transistor amplifier with a power of 30 W using KT907A transistors in the output stage working into a load resistance of 20 ohms with a center frequency of the filter of 9 KHz. The switching relay circuit was a Schmidt trigger designed around a K1LP331 IC. Figures 3; references 3: 2 Russian, 1 Western.  
[11-8225]

## THE STABILIZATION OF THE CHARACTERISTICS OF A REGENERATIVE PARAMETRIC AMPLIFIER BY MEANS OF BIHARMONIC PUMPING

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 37-41 manuscript received 12 Jun 79

NADVORNYI, M. M. and TARABRIN, Yu. K.

[Abstract] A regenerative parametric amplifier is shifted over to biharmonic from single-frequency pumping with the addition of a supplemental pumping source operating at half the frequency  $f_p$  (where  $2f_p$  is the amplifier pumping frequency in the single-frequency case). The amplifier employing this subharmonic pumping configuration contains tuned circuits at the frequency of the input signal,  $f_{in}$ , and the idler frequency,  $f_2 = 2f_p - f_{in}$ . This variant for the transition to biharmonic pumping is of interest in the design of microwave parametric amplifiers where it is difficult

to increase the pump and idler frequencies; this paper analyzes such a configuration and demonstrates the possibility of reducing the sensitivity of the gain to variations in the pumping power and impedance of the input signal source, while maintaining low internal noise levels in the dual tuned circuit amplifier with the supplemental subharmonic pump. Analytical expressions are given for the gain and effective relative noise temperature. Criteria governing the amplifier stability close to the minimum internal noise point are discussed and the theoretical conclusions are checked experimentally using a breadboarded amplifier in the 3 cm band with a low Q diode ( $Q = 5 - 6$ ). An effective noise temperature of  $290 \pm 30^\circ \text{K}$  was obtained, while the gain exhibited no sensitivity to variations in the amplitude of the second pumping harmonic; this noise temperature is 70% of the figure for the same parametric amplifier with single frequency pumping at the second harmonic. The agreement between experiment and theory is illustrated graphically. Figures 5; references: 4 Russian.  
[11-8225]



CERTAIN ASPECTS OF COMPUTER HARD AND SOFTWARE:  
CONTROL, AUTOMATION, TELEMECHANICS, TELEMETERING,  
MACHINE DESIGNING AND PLANNING

UDC 621.3.049.777.14.001.573

AN ANALYSIS PROGRAM FOR THE ELECTRICAL CHARACTERISTICS OF INJECTION POWERED LSI  
FRAGMENTS

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 8-13 manuscript  
received 8 Feb 79, after revision 24 Dec 79

DASHCHENKO, V. P. and MAKAROV, V. A.

[Abstract] Computer time and mainframe memory requirements for the analysis of the electrical characteristics of  $I^2L$  LSI circuits can be reduced if the electrical processes are analyzed in terms of topological fragments. Such fragments are segregated from the topological drawing of the LSI circuit based on the criterion of repeatability and take the form of chip sections corresponding to functional units. The LSI fragments are treated as macroelements in the analysis; at the electrodes of the elements, definite relationships are established between the currents and voltages. This paper proposes a program for the automated analysis of the static and dynamic characteristics of such fragments, and in contrast to previous programs, permits the mathematical modeling of the characteristics of such  $I^2L$  topologies without manually drawing their equivalent circuits. The program is written in FORTRAN-IV for the YeS computer series with disk operating systems. It is possible to analyze LSI fragments containing up to 150 transistors (with computers having a memory capacity of 64 K). The program modeling requires an outline of the topology and the electrical parameters of the p-n junctions of the LSI components. The procedure for encoding the topology of a fragment is described and the new program is compared with the earlier PA-1 routine as applied to the analysis of a flip-flop IC fragment containing 14 transistors; the comparison shows that machine time expenditures were reduced by a factor of 2.6. Figures 2; references: 6 Russian.

[11-8225]

CALCULATION OF THE OPTIMAL CUTOFF VOLTAGES FOR DEPLETED MOS TRANSISTORS FOR DIGITAL STATIC LOGIC MOS CIRCUITS

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, pp 3-7 manuscript received 29 Apr 79, after revision 26 Oct 79

KHODOSH, L. S. and CHEREPENNIKOV, V. M.

[Abstract] Static logic MOSFET LSI circuits using MOS transistors with incorporated channels (depleted devices) are employed as load components in various types of electronic circuits; these circuits are broken down into three groups: 1) Logic gates with depleted loads, using bipolar circuitry; 2) Flip-flop memory elements with micropower depleted loads; and 3) Buffer push-pull stages with active depleted loads which are gate controlled. A procedure is proposed for calculating optimal cutoff voltages for ion doped depleted MOS devices for digital n-channel static logic gates, based on the criterion of the best power-operational speed product. The justification for using various types of depleted MOS loads with high and low cutoff voltages is illustrated briefly with two random access static memories: the Intel Corp. 2102A and 2147 devices. Figures 3; references 9: 7 Russian, 2 Western. [11-B-8225]

UDC 519.283

THE POTENTIAL COST OF RADIO LINKS FOR INFORMATION RECOVERY USING SPACED ANTENNAS

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 55-60 manuscript  
received 19 Jun 79

GUTKIN, L. S.

[Abstract] A radio link in which the receiver can be located at a considerable distance from the transmitter and thus has a separate antenna is analyzed to determine the potential cost, given four definitions of this cost: 1) The unconditional potential cost (UPC) is the minimum value of the cost, assuming that the only interference is additive normal white noise and the data processing is ideal (realizes the potential noise immunity), is cost free, and there are no limitations from the top on the variable parameters (for the purpose of cost minimization); 2) Conditional potential cost of the first kind, which differs from UPC only in that the data processing is not ideal (but remains free of charge) 3) Conditional potential cost of the second kind, which differs from UPC only in that the limitations at the top on the variable parameters are taken into account; and 4) Conditional potential cost of the third kind, which differs from the first kind only in that the topside limitations on the variable parameters are taken into account. Analytical expressions are derived for the potential cost of radio links in the above four cases, given various assumptions: 1) The requisite signal-to-noise ratio does not depend on the power parameters of the link; and 2) This ratio depends on the area of the receiving antenna. A procedure is given for potential cost determination taking into account the topside limitations on the variables. References: 1 Russian. [11-8225]

# A FREQUENCY DETECTOR WITH THE CONVERSION OF FREQUENCY MODULATION TO PULSE TIME MODULATION

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 94-95 manuscript received 28 Mar 79, after revision 11 Feb 80

VLASENKO, V. A. and JAEGER, D.

[Abstract] The input signal to a standard IF channel (with an intermediate frequency of 10.7 MHz) is converted in a second mixer to 500 KHz, which is then fed to the input of an FM detector. Following amplification, the signal is fed to a heavy limiter: a cascaded Schmidt trigger and a complementary flip-flop. The output signal of the flip-flop is fed to the input of the complementary detector, which consists of a differentiating network with a varicap, the capacitance of which is controlled by the bias voltage of a transistor switch in a common base configuration, the load on which is an integrator which integrates the pulses of the collector current. The number of pulses is proportional to the frequency of the detected signal. Expressions are adduced for the detector output voltage and the nonlinear distortion. The proposed design is simpler than PLL circuits, and has a wide bandwidth plus low dynamic distortion. Figures 2; references 4: 3 Russian, 1 Western.  
[11-8225]

# THE CALCULATION OF THE IMPACT OF RADIO PULSE INTERFERENCE ON FREQUENCY MODULATED RADIO RELAY LINKS VIA SPURIOUS RECEPTION FREQUENCIES

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 77-78 manuscript received 24 Apr 79

SHCHERBAKOV, A. F.

[Abstract] Because radar stations can share the service bands of FM space and radio relay links, the radar transmitters can interfere with the latter. This paper analyzes the impact of interference on multichannel FM links via the spurious receive channels which arise because of interaction between the interfering signal and its harmonics with the local oscillator voltage and its harmonics. An equation is adduced for the psophometric power of the nonlinear crosstalk noise in such FM relay systems. The derived equation indicates that it is necessary to know the change in the power spectrum of the useful signal, taking into account the amplitude-frequency response of the spurious receive passband in order to compute the power of pulse interference in telephone channels. This knowledge substantially simplifies the analysis of the effect of the interference for various values of the frequency difference between the interference and the signal, as well as when the interference parameters change (the pulse width, repetition rate). Curves showing the change in the

interference power in the upper telephone channel of a system as a function of the frequency difference are plotted graphically for a sample case. It is noted that in the reception of pulsed interference via spurious side channels, the frequency offset on both sides of the center frequency is not equal, which contrasts with the case of interference acting through the primary channel. Figures 1; references: 6 Russian.  
[11-8225]

UDC 621.396.622.2

#### COMPENSATING FOR COMBINATION DISTORTIONS IN A MICROWAVE MIXER

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 91-93 manuscript received 4 Dec 78, after revision 14 Jan 80

ANISIMOV, Ye. N., ASTASHKEVICH, B. A. and KHOTUNTSEV, Yu. L.

[Abstract] A procedure is proposed for signal frequency conversion, which produces combination components, and conditions are found where terms are compensated at a given frequency. The procedure is an approximation technique, because it assumes low signal and local oscillator levels, i.e., it applies to combination components of the fourth order of smallness. The qualitative results of the calculation because of the possibility of such compensation is demonstrated. The microwave mixer is represented as a two-pole equivalent circuit, the relevant equations are written and solved for the currents in the system and then, using the example of a Schottky barrier diode, the theoretical expressions are checked experimentally. In one experiment, the level of the combination component  $2f_{\text{sig}} - 2f_{\text{loc.osc.}}$  at the output of the mixer was measured as a function of the diode current and the local oscillator voltage. The measurements confirmed the feasibility of suppressing combination interference, showing a suppression depth of 18 - 20 dB. Another mixer using a correcting network inserted ahead of the diode in order to match the diode to the signal source was studied; the gain in the sensitivity was 10 - 12 dB. The compensation is plotted graphically as a function of various mixer parameters and the impact of these parameters on mixer performance is discussed briefly. Figures 4; references: 1 Russian.

[11-8225]

THE DYNAMIC RANGE OF A RESISTIVE ELECTRICAL MICROWAVE FIELD INTENSITY SENSOR AND  
THE POSSIBILITIES OF EXTENDING IT

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 65-69 manuscript  
received 28 Jun 79

DAGIS, M. I. and SKUCHAS, Yu. P.

[Abstract] The assumption that the output voltage of a resistive semiconductor field transducer is proportional to the voltage drop across it when supplied with a stable DC current is in considerable error in the case of high field intensities because of the heating of the free charge carriers and Joule heating of the semiconductor lattice. Previous empirical approaches to the determination of the volt-ampere characteristic of such sensors treated only those field intensities above  $2 \cdot 10^5$  v/m; the resulting expressions are not suitable for the description of the V-A characteristic of silicon in fields from  $10^2$  to  $10^6$  v/m. This paper derives a simple empirical formula for the V-A characteristic and is suitable for the analysis of resistive transducer in microwave fields. The dynamic range of such a sensor is determined as a function of its DC response and ways of expanding the range through linearization of the amplitude response of the transducer are indicated. The dynamic range of one proposed transducer reaches 40 to 45 dB with an output signal of up to 10 v, where the deviation from a linear response does not exceed 1 to 2%. The basic results of this paper are not linked to the structural design of the transducer and thus generally apply to all silicon resistive transducers. Figures 3; references 9: 6 Russian, 3 Western.  
[11-8225]



ELECTRICAL ENGINEERING EQUIPMENT AND MACHINERY:  
APPLICATIONS AND THEORY

UDC 621.313.2.047.4

A STUDY OF THE OPERATION OF PARTIALLY SUBSECTIONED BRUSHES ON AN ALUMINUM COMMUTATOR

Novocherkassk IZV. VUZ: ELEKTROMEKHANIKA in Russian No 8, Aug 80 pp 811-813 manuscript received 27 Sep 79

KLUSHIN, Yu. P., laboratory chief of the Tomsk Electrical Engineering Plant, TUKTAYEV, I. I. and KHLYSTOV, M. F., candidates of technical sciences and senior scientific research workers, Scientific Research Institute for Electromechanical Engineering, Tomsk

[Abstract] Partially split, pliant brushes can be employed on an aluminum commutator to replace the traditional copper commutator and to increase the mechanical durability of the sliding contact. The aluminum-to-brush sliding contact was tested using cylindrical and segmented aluminum commutators consisting of two split rings; the working area of the aluminum commutator of the test motor was made in the shape of a 90° triangular notch in the face of the brush, with the brush split in the center at the vertex of the notch by a slot running deep into the brush in order to produce pliancy. Test motor sets were used to determine the rate of brush wear and the permissible current densities in the case of sparking rated at 1.25 points on a 12 point scale, with no sparking and with various working section inductances. A type EG-74 brush with dimensions of 10 mm x 12 mm x 20 mm was used at a speed of 5,000 r.p.m. and a commutator diameter of 58.5 mm. The pressure on the brush was 2.256 N. In the absence of inductance in the commutating section, no sparking was observed at the trailing edge of the pliant brush up to 100 A/cm<sup>2</sup>, while sparking does appear in the nonslotted counterpart on an aluminum commutator at current density of 20 A/cm<sup>2</sup>. The wear for the two types of brushes was measured after 100 hours; the slotted configuration showed the ability to continue for a total of 1,500 hours while the service life of the other is computed as 200 hours. The wear of the pliant brush is an order of magnitude less than the wear of the standard brushes both on aluminum and copper commutators. Volt-ampere characteristics plotted for the conventional copper ring and the aluminum contact ring show that the latter retains a constant contact resistance at elevated current densities; the positive results of comparative tests of a variety of electrical machines with aluminum commutators argue in favor of further studies of such pliant contacts under various conditions. Figures 3; references: 2 Russian.  
[26-8225]



## PENETRATION OF A PULSED MAGNETIC FIELD INTO A FERROMAGNETIC PLATE

Moscow ELEKTRICHESTVO in Russian No 8, 1980 pp 30-33 manuscript received 12 Sep 79

KHIMENKO, L. T., Khar'kov Polytechnical Institute imeni V. I. Lenin

[Abstract] A demonstration is given of the fact that considerable errors result when the ferromagnetic properties of ferromagnetics in strong magnetic fields are disregarded in the consideration of electromagnetic processes. It is shown that the ferromagnetic properties of a plate, even when it is heavily saturated, have a substantial influence on the nature of the distribution of current strength and density over the plate's thickness. When the ferromagnetic properties of a plate are taken into account, the penetration of the magnetic field strength wave into it and the establishment of current density over its thickness take place considerably more slowly than in the case when the plate is considered to be magnetized at once to the point of saturation. The process of the penetration of a pulsed magnetic field into a plate is described by the system of equations  $\partial^2 H / \partial x^2 = \mu_n \gamma (\partial H / \partial t)$ ,  $\partial^2 B / \partial x^2 = \mu_n \gamma (\partial B / \partial t)$ , where  $H$  is the strength of the magnetic field,  $\mu_n$  is the magnetic permeability of the ferromagnetic in the saturated state,  $\gamma$  is the conductivity of the material and  $B$  represents induction. The electromagnetic process is discussed for massive plates when the condition  $z_k < d$  is observed, where  $z_k$  is the critical depth of penetration of an electromagnetic wave into a ferromagnetic and the thickness of the plate is represented by  $2d$ . Under this condition for sufficiently long time periods, when the wave is not able to reach the middle of the plate, the following inequality is valid:  $\sqrt{\mu_n \gamma} z_k / 2\sqrt{t} < 1$ . At this first stage electromagnetic waves penetrating the plate do not influence one another; only with  $z_k \geq d$  is the process in the plate caused by electromagnetic waves having penetrated the plate from both sides, representing the beginning of the second stage. The above inequality is practically always observed in devices used for technological purposes and for producing strong magnetic fields. Equations are derived for induction, for current density at the first stage and for the change in current density at the second stage. Curves are plotted for the magnetic field strength and current density. The results obtained are compared with a familiar equation given in an earlier study (1972) describing the diffusion of a pulsed magnetic field in a nonferromagnetic plate. Figures 5; references: 7 Russian, 1 Western (in translation).

[46-8831]

# THE ANALYTICAL GRAPHICAL DESIGN OF FRAME CORE FERROMAGNETIC PROBES WITH PULSE EXCITATION

Novocherkassk IZV. VUZ: ELEKTROMEKHANIKA in Russian No 8, Aug 80 pp 874-878 manuscript received 11 Jun 79, after completion 9 Jan 80

SMIRNYY, M. P., candidate of technical sciences and dotsent, Voroshilovgrad Machine Building Institute

[Abstract] The signal patterns magnetically stored in such unconventional media as railroad rails, steel pipes, cables and rolled metal can be read out by modulated magnetic transducers: ferromagnetic probes. This paper analyzes a ferromagnetic probe with a pair of pickup differential windings wound on two parallel legs of a rectangular strip frame made of a magnetically soft material with a nonrectangular hysteresis loop; the secondary windings are also wound on the same parallel legs forming the long side of the frame core. The ratio of the long to short sides is 4:1. A differential equation is written and solved to find the dynamic response of this transformer sensor. The analytical expressions are used to find the waveform of the output signal of a sample transducer with the following parameters: the number of turns in the excitation windings is  $2 \times 50$  turns, and in the output windings,  $2 \times 250$  turns; the core thickness is 0.1 mm with the width of the frame legs of 5 mm; the dimensions of the frame: 40 mm long and 10 mm wide; the external field intensity is 70 A/m, the e.m.f. of the excitation pulse source is 16 volts with a pulse width of 12 microseconds. The divergence between the experimental and theoretical results is no more than 10%. Figures 4; references: 4 Russian. [26-8225]

# ENERGY LOSSES IN A MAGNETIC STEP-UP PULSE SHAPING TRANSFORMER

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 102-104 manuscript received 19 Jul 79

KONONOV, A. I.

[Abstract] An analytical expression is adduced for the hysteresis energy losses in a nanosecond pulse transformer core; the analysis of this equation is used to ascertain the optimal transformer design for a specified frequency, based on a minimum of the transformer losses for a given primary inductance with core saturation. A proposed configuration shows a single turn primary winding in the form of an annular cavity in which a ferrite ring is placed with the secondary wound on it, where the cavity also contains a choke core. Design considerations are discussed and it is indicated that the equations derived here are confirmed by numerous experiments, though only one of these experiments is briefly described, showing agreement for the energy loss figure within 20%. Figures 3; references: 2 Russian. [11-8225]

UDC 621.822.5:621.318.2(088.8)

CALCULATION OF THE REPULSION FORCE BETWEEN TWO RECTANGULAR MAGNETIC PRISMS IN THE CASE OF THE HORIZONTAL DISPLACEMENT OF ONE PRISM RELATIVE TO THE OTHER

Novocherkassk IZV. VUZ: ELEKTROMEKHANIKA in Russian No 8, Aug 80 pp 782-787 manuscript received 18 Oct 79

BUL', B. K., doctor of technical sciences, professor, Moscow Power Engineering Institute, GAVRILOV, G. G., candidate of technical sciences, dotsent, Kirov Polytechnical Institute, and KRASNYKH, A. A., graduate student, Moscow Power Engineering Institute

[Abstract] Inasmuch as the prospects for magnetic suspensions using the repulsion of like poles of permanent magnets are promising because of the appearance of materials having a high coercivity, this paper analyzes the repulsion between a pair of magnets in the shape of rectangular solids. In addition to being spaced a certain distance apart, the prisms are shifted relative to each other horizontally (along the long axis of the solid magnet which runs between the two opposite poles). The magnetostatic integrodifferential equation is written for the repulsion force and solved to derive a rather cumbersome expression for this force. The calculation is accomplished numerically with a program written for the Mairi-K digital computer. The behavior of the repulsion force is then tested experimentally with magnets fabricated from type 1B1 barium ferrite material. Experimental and theoretical values of the force are shown graphically as a function of both the rectangular solid dimensions and horizontal displacement and separation for configurations of up to eight pairs of magnets. Good agreement is noted between theory and experiment. Figures 7; references 5: 3 Russian, 2 Western (1 in translation).  
[26-8225]

## INVESTIGATION OF OPTICAL CHARACTERISTICS OF SOLAR CELLS BASED ON A METAL-OXIDE-SEMICONDUCTOR STRUCTURE

Tashkent GELIOTEKHNIKA in Russian No 3, 1980 pp 67-69 manuscript received 19 Jul 79

ARSENIN, V. V., KOLTUN, M. M. and KULAGIN, A. I., Uzbek SSR Academy of Sciences Institute of Electronics imeni U. A. Arifov

[Abstract] An experimental investigation is made of the influence on the photoelectric characteristics of metal-oxide-semiconductor (MOS) solar cells of the parameters of the starting material and of key elements of their design, such as the orientation and quality of the polishing of silicon wafers, the thickness of the interstitial oxide and sprayed depletion-layer metal, and the optical characteristics of thin metallic films. Solar cells were fabricated as follows. Silicon wafers with a resistivity of  $1 \Omega \cdot \text{cm}$  oriented in planes [111] and [100] were polished on both sides in an etchant based on SP-4. Some wafers were polished mechanically in order to produce a surface finish of  $\Delta 14$ . The back side was doped by means of Al diffusion of reduce contact resistance. When the wafers were dried an aluminum contact about 1 micron thick was sprayed onto the back side and an oxide film was grown on the front side, in air at  $420^\circ\text{C}$  over periods varying from 10 min to 1 h. An ellipsometer was used in order to measure the thickness of the oxide. The back contact was brazed at the same time. The wafers were then placed in a vacuum chamber and at a pressure of  $5 \cdot 10^{-5}$  mm Hg the depletion-layer metal (aluminum) was sprayed on, with its thickness monitored in the spraying process. Onto the aluminum film was then sprayed an aluminum comb-type contact with a spacing of 2 mm and about three microns thick. The optimum thickness of the depletion-layer metal was selected from the preliminary results of measuring the transmission and reflection coefficients and the film resistance of a metallic film on glass and on silicon and the dependence of these coefficients on the wavelength of the light. A film of titanium served as the brightening coating. The interstitial oxide film is a key element of the structure and the short-circuit current, open-circuit voltage and the efficiency of the transducer depend on the thickness of the oxide film. The optimal thickness of this film is 20 Å. Solar cells with an oxide film thickness of 13 and 14 Å were made from silicon wafers oriented in planes [100] and [111]. The quality of polishing was different for the individual wafers. The cells measured  $5 \text{ cm}^2$ . The results are given of measurements of the open-circuit voltage and short-circuit current of the fabricated solar cells when illuminated by a tungsten lamp and by a simulator of solar radiation, with different thicknesses of the interstitial oxide film. The results demonstrate that the quality of polishing the silicon wafers is of great importance in the technology for fabricating MOS solar cells. The highest value of the open-circuit voltage was obtained in wafers polished to an optical surface finish



Δ14. Regardless of low-quality polishing of the front surface, elements made from wafers with orientation [100] have better characteristics. Photosensitivity is improved by increasing the thickness of the oxide film from 12 to 14 Å. MOS solar cells evidence improved photosensitivity in the shortwave region of the solar spectrum as compared with those fabricated by diffusion processes. Figures 1; references: 1 Russian.  
[23-8831]

UDC 662.997:536.22

#### INVESTIGATION OF THE OPTICAL PROPERTIES OF A TEXTURED SILICON SURFACE

Tashkent GELIOTEKHNIKA in Russian No 3, 1980 pp 15-17 manuscript received 20 Feb 79

GOLOVNER, T. M., ZAYTSEVA, A. K., MARASANOVA, E. A. and POLISAN, A. A., All-Union Order of the Red Banner of Labor Scientific-Research Institute of Current Sources

[Abstract] A study is made of the optical properties, of the reflection coefficient in particular, of the texture produced by treating in isotropic etchants polished silicon wafers oriented in plane (100) and with a deviation of as much as  $10^\circ$  from this orientation. With the latter orientation the texture is in the form of a group of inclined pyramids whose height is not perpendicular to the plane of the silicon wafers. The wafers were treated in an aqueous solution of hydrazine hydrate with the addition of pyrocatechol at elevated temperature. The height of the pyramids forming the texture was 1 to 3 microns. An SP-10 spectrophotometer was used to measure the reflection coefficient in the wavelength range of 0.4 to 0.75 microns. Curves are shown, illustrating the spectral dependence of the reflection coefficient for a textured silicon surface with inclined pyramids, for silicon wafers with polished surfaces produced by different methods of treatment, and with ground surfaces produced by abrasives with various degrees of coarseness. The curves show a substantial difference in the reflection coefficient for the textured surface with inclined pyramids. Its reflection coefficient is much lower because of double reflection of the major portion of the radiation from adjacent sides of the pyramids. The difference in the reflection coefficient is caused by that portion of the radiation which is being reflected from one side does not strike an adjacent side, i.e., is reflected only once. For a textured surface with inclined pyramids, and with pyramids of different heights, the percentage of light reflected once, of the total flux of reflected radiation, is changed. The difference in reflection coefficients is somewhat reduced after a ZnS coating is applied to a textured surface with inclined pyramids. When glass is cemented to a textured surface by means of a transparent adhesive the difference in the reflection coefficients is eliminated completely, regardless of whether the glass is cemented to a coated or uncoated textured surface. This is explained by the fact that the part of the radiation reflected once strikes the glass-air interface at wide angles greater than the angle of total internal reflection and does not exit, i.e., does not make its contribution to the overall reflection coefficient. It is concluded that in fabricating photocells with a textured surface whose design calls for protective glass there is no need for the precise orientation of silicon wafers in plane (100) and that the effect of coating the textured surface is relatively slight when protective glass is used. Figures 2.

[23-8831]

## EQUIPMENT FOR REGULATING RADIANT FLUX IN SOLAR UNITS

Tashkent GELIOTEKHNIKA in Russian No 3, 1980 pp 22-24 manuscript received 4 Sep 79

KHAKIMOV, R. A., ZAKHIDOV, R. A. and SIZOV, Yu. M., Uzbek SSR Academy of Sciences Central Planning, Design and Technological Bureau of Scientific Instrument Making

[Abstract] A description is given of a unit for regulating solar radiant flux in the form of a heliostat with adjustable blinds and a concentrator with facets furnished with orientation sensors which control drives by means of control units. When automatically following the sun, the surface of the heliostat is completely exposed. When it is necessary to control the degree of admission of radiant flux, precision drives are turned on which move small carriages on top of the heliostat which are attached to bent rods which are in turn attached to the ends of window-shade-type blinds, which close over the front surface of the heliostat. The axes of the closing edges of these blinds are perpendicular to the horizontal axis of the heliostat. When the blinds are completely closed, some light can be admitted through a small rectangular slot formed by a single notch in the edge of either blind, which meet when the blinds are closed. The drives can be remote controlled or can be controlled by means of an automatic flux regulator. The precision drives make it possible to close or open the blinds with a degree of accuracy of 5 mm. A speedy drive is also supplied to make it possible to cover the entire surface of the heliostat quickly when required. The blinds also serve the purpose of protecting the surface of the heliostat from precipitation in emergencies. The light flux of the solar furnace for which this heliostat was designed can also be regulated by disorienting the individual facets of a sectional concentrator, either individually according to an assigned routine, or all at once over the entire surface of the concentrator. On the facets, parallel to the optical axis of the concentrator, photoelectric orientation sensors are installed which control drives by means of control units. The angle at which the sensors are installed is equal to the angle between the direction of the beam reflected from the facet and passing through the focal point of the concentrator, and the normal line to the facet. The power at the focal point can be regulated in steps of 5 to 10 kW in the range of 1000 kW and higher. Figures 2; references 4: 3 Russian, 1 Western.

[23-8831]

INSTRUMENTS, MEASURING DEVICES AND TESTERS, METHODS OF  
MEASURING, GENERAL EXPERIMENTAL TECHNIQUES

UDC 621.317.757

A DUAL STAGE DIGITAL SPECTRUM ANALYZER

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 49-54 manuscript received 26 Jun 79, after revision 20 Nov 79

BAKULEV, P. A. and LITYUK, V. I.

[Abstract] A two-stage digital spectrum analyzer, which realizes a discrete Fourier transform algorithm, is studied; such analyzers have a greater range of unambiguous spectrum analysis than digital recirculating types. Using three block diagrams, two proposed complex signal two-stage analyzers are compared with the single stage counterpart. The former differs from the latter in having only one immediate access memory in the signal processing train and fewer switches, although the main components are the same: an input bandpass quadrature phase inverter, analog to digital converter, adder, complex number multiplier, units for squaring and extracting square roots and an output digital to analog converter. Analytical expressions are adduced for the quantization noise and rounding-off error; estimates are also obtained for equipment costs and sample calculations show that a reduction of 14.4% in overall memory capacity is possible as compared to the single stage configuration. Figures 4; references: 2 Russian.  
[11-8225]



PHOTOELECTRIC PHENOMENA AND DEVICES,  
ELECTROLUMINESCENCE, ION DEVICES

UDC 621.383.292

THE DARK CURRENT OF A PHOTOMULTIPLIER OPERATED IN THE NEAR CATHODE MODULATION MODE

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 97-99 manuscript received 31 May 79, after revision 17 Dec 79

PETRUKHIN, G. D. and MARTYUSHEV, Yu. Yu.

[Abstract] The dark current of a photomultiplier when near-cathode modulation is employed, as in the case of optical rangefinders, can be broken down into three regions as a function of the heterodyne voltage. The first is where the dark current falls off with an increase in the heterodyne voltage; a second region of relatively constant dark current and a third region of rather sharply increasing dark current with a rise in the heterodyne voltage are observed. This paper describes a number of studies investigating the behavior of the dark current as a function of the heterodyne voltage. The distribution of the electrical field in the cathode chamber at various local oscillator voltage levels was modeled on a computer for the simple case of a uniform heterodyne voltage distribution over the cathode surface and a very simple cathode chamber design with central axial symmetry. Experimental curves are also shown for heterodyne frequencies of 80, 60 and 45 MHz for FEU-51 photomultipliers, which illustrate the agreement between theory and experiment, though specifics of the experiments are not given. Figures 3; references: 6 Russian.

[11-8225]

## INVESTIGATION OF ENERGY CHARACTERISTICS OF PHOTOTHERMAL CONVERTERS

Tashkent GELIOTEKHNICA in Russian No 3, 1980 pp 7-11 manuscript received 8 Jan 80

BORISOV, S. N., GORODETSKIY, S. M., IORDANISHVILI, Ye. K., KAGAN, M. B., KASYMAKHUNOVA, A. M., LYUBASHEVSKAYA, T. L. and DOROKHINA, T. P., Leningrad

[Abstract] A photothermal converter is a combined semiconductor device employing both the photoelectric and thermoelectric methods of converting energy. It consists basically of a photocell and a thermocouple. It was demonstrated that a photothermal converter can under certain conditions have higher efficiency than that of a photocell functioning at room temperature. The results are given of an experimental study of a photothermal battery which has been developed. The photobattery included in the photothermal battery consists of four photocells connected in parallel and selected to have minimum series resistance and a minimum temperature coefficient of power. The area of the photobattery is  $4.2 \text{ cm}^2$  and the photocells are soldered to four metalized ceramic wafers with high thermal conductivity, which in turn are soldered directly onto the switching plates of the hot junctions of the thermocouples of a thermal battery. The thermal battery measures  $20 \times 20 \times 17 \text{ mm}^3$  and consists of eight series-connected thermocouples with arms measuring  $4 \times 4 \times 13 \text{ mm}^3$  made of the ternary alloys BiTeSb (p-type) and BiTeSe (n-type) produced by the zone melting crystallization method and having a maximum thermoelectric efficiency of  $3 \times 10^{-3} \text{ deg}^{-1}$  at 20 to  $40^\circ\text{C}$ . The cold junctions of the thermal battery are soldered via a metalized ceramic to a copper heat sink. The photothermal battery was placed in a vacuum chamber and light was admitted through a quartz window from a tungsten motion picture lamp with an elliptical reflector and a spherical cap. Light was focused on a spot measuring about  $25 \times 25 \text{ mm}^2$  and the light spot was measured photometrically by means of a photometer and by employing a type IMO-2 pulsed laser. The latter was used to calculate the mean density of luminosity and the total power of the light striking the photothermal battery. A silicon photodiode was used as a light intensity sensor and it was connected to a recorder in order to keep the light intensity constant. The light beam was filtered through a water filter 20 mm thick. The intensity of the light could be set from 0.6 to  $2.5 \text{ W/cm}^2$  and its spectral composition was determined by the color temperature of the K-22 motion picture lamp, which varied from 1800 to  $2500^\circ\text{K}$ . The current and voltage of the photobattery and thermal battery and the temperature of the photobattery and hot junctions of the thermal battery and the temperature of the heat sink were recorded by means of a KSP-4 recording potentiometer. Circulating water from an ultrathermostat maintained the temperature of the cold junctions at a constant level of  $+20^\circ\text{C}$ . For lower temperatures the heat sink was cooled by means of nitrogen vapors. For this purpose an electric heater placed in a Dewar flask with liquid nitrogen was used to regulate the current by means of which the KSP-4 unit automatically held the temperature constant. Equations are presented for the efficiency of the photobattery, thermal battery and photothermal battery. Curves are presented, illustrating the dependence of the efficiency of the photothermal battery and of the photobattery and thermal battery contained in it on the temperature of the photobattery and of the hot junctions of the thermal battery when the batteries are connected to optimal loads. They also distinctly show the dependence of these quantities on the intensity and spectral

composition of the light. With a rise in temperature of the photobattery its efficiency drops and at the same time the efficiency of the thermal battery increases. The efficiency of the thermal battery is determined by the difference in the temperatures of the hot and cold junctions and a drop in the temperature of the cold junctions of the thermal battery results in an increase of the efficiency of the photothermal battery. It is demonstrated that the efficiency of a photothermal battery is considerably greater than the efficiency of a photobattery at room temperature and that it is greater, the lower the temperature of the thermal battery's cold junctions. By coating photocells and by reducing their series resistance it will be possible to increase the efficiency of photothermal batteries by increasing the efficiency of the photobattery. By reducing the series resistance of photocells it will be possible to use them with higher light intensities, thus resulting in an increase in the temperature of the thermal battery and a resulting increase in the contribution of the thermal battery to the overall efficiency of the photothermal battery. Figures 2; references: 9 Russian.  
[23-8831]

UDC 621.396.624.001.5

#### A STUDY OF THE PROBABILITY DISTRIBUTION FUNCTION FOR CURRENT FLUCTUATIONS IN AN AVALANCHE PHOTODIODE

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 95-97 manuscript received 23 Mar 79, after revision 2 Jan 80

IVANOV-TSYGANOV, A. I. and MERKISHIN, G. V.

[Abstract] It has been previously established that the fluctuations probability distribution function of the multiplied current in an avalanche photodiode can be a normal distribution; still, with a small number of charge carriers injected into the multiplication region, the process takes on a pulsed nature and the boundary separating these two behaviors has been determined only analytically in the literature. This paper is an experimental check of the normal distribution applicability in this case. A silicon avalanche photodiode with a breakdown voltage of 40 volts was used in the test circuit, with an injection current in the multiplication region. A constant bias voltage of about 38.5 volts as well as 5 nanosecond wide pulses with an amplitude of 1.5 volts were fed to the diode; high multiplication factors were achieved during the pulses. The experimental curves for the probability function are plotted and superimposed on the theoretical values, showing good agreement. A criterion is proposed for the difference between the normal distribution and the distribution functions of the diode current fluctuations; it is demonstrated that this criterion can be used in order to determine the boundaries of the region in which the distribution is close to normal and the experimental results also confirm the conclusions of the theoretical treatment by G. V. Merkishin [RADIOTEKHNIKA I ELEKTRONIKA, 1978, No 1, p 205]. Figures 4; references 5: 3 Russian, 2 Western.  
[11-8225]

UDC 621.316.1.027

NECESSITY OF USING 20 kV VOLTAGE IN DISTRIBUTION SYSTEMS OF ENTERPRISES AND CITIES

Moscow ELEKTRICHESTVO in Russian No 8, 1980 pp 58-59 manuscript received 24 Jan 80

FEDOROV, A. A., doctor of technical sciences and professor, KAMENEVA, V. V., candidate of technical sciences, CHERNUSSKIY, A. I., engineer, STEBUNOVA, Ye. D., candidate of technical sciences, and SIDEROV, S. T., engineer, Moscow

[Abstract] The use of 20 kV voltage in the distribution systems of cities and industrial enterprises has been necessary as far back as the 50's and 60's. But the changeover to this voltage has been delayed because of the lack of appropriate equipment. The case is presented for the necessity of immediately changing over to 20 kV voltage. This changeover will make it possible not only to reduce losses in lines, but also to increase the servicing radius of substations and to reduce the number of transformations. Some results are given of a scientific research study to determine the efficient voltage for the Mosoblektro [Moscow Oblast Administration of Electric Power Plants and Networks] System, conducted at the Moscow Energy Institute in the industrial enterprise electrical service department. The annual cost of losses of electric power in Moscow Oblast in distribution systems alone, resulting from the use of 6 and 10 kV voltage instead of 20 kV, equals 19.35 million rubles. Nevertheless, steady resistance has been given to introducing 20 kV voltage, the reason given being the need to build new plants in order to produce the appropriate electrical equipment. It is demonstrated that it is not necessary to build new plants in order to construct new transformers. It is easy to produce transformers with a 220-110/20 kV voltage by uncomplicated switching of the windings from a wye connection to a delta connection at the lower voltage end in the modern transformers presently produced by the Ministry of the Electrical Equipment Industry and having a wye connection with a grounded neutral - wye connection winding arrangement for 220-110/35 kV. It is also not necessary to produce new contact breakers, for all CEMA countries produce breakers for a rated current of 400 to 1200 A and a voltage of 20 kV. The use of 20 kV breakers will result in a drastic reduction in the number of breakers in electrical supply systems. The increase in the cost of fuses will be not greater than one percent. It is shown that the consolidated cost figures for technical and economic calculations used in planning have been overstated. In actuality the cost of 20 kV equipment is considerably lower than the cost of 35 kV and differs little from that of 10 kV. The cost of 20 kV equipment has been overstated in the USSR because expenses for carrying out scientific research studies and for making experimental models have been imputed to the cost of 20 kV equipment. For comparison, data are presented on the cost of the 20 kV equipment used in the electrical distribution systems of the People's Republic of Bulgaria. Figures 3; references: 3 Russian.  
[46-8831]



UDC 621.396.6.002.72:658.512:681.3

AN ALGORITHM FOR SYNCHRONIZING THE CONVEYOR LINES FOR THE ASSEMBLY OF RADIO ELECTRONIC EQUIPMENT

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 99-102 manuscript received 23 Jan 79, after revision 4 Jun 79

GAVRILOV, B. G., SAMKOV, Ye. Ya., TKACH, M. P. and TYNINYKA, A. N.

[Abstract] A heuristic scheduling algorithm is proposed for the control of a production line for radioelectronic equipment assemblies. The algorithm generates time-wise balanced sets of production components, where the number of production elements are identical or differ as little as possible. The production process sets produced by this algorithm differ in the diversity of the components incorporated in them, something which from the viewpoint of psychological and physiological requirements has a positive impact on the labor of the workers, because it reduces the monotonous nature of the work. The program was written in FORTRAN-IV and experimentally run on a YeS-1020 computer; the machine time required for the realization of the initial scheduling distribution for assemblies of 150 to 200 components did not exceed 50 seconds, and no more than 3 minutes for the entire algorithm. The routine is predicated on the assumption that the number of work positions on the production line, the number of components to be assembled, each of which is characterized by a specific difficulty of assembly, and the maximum permissible value of the loss of synchronization of the line are specified. Figures 2; tables 1; references: 2 Western (1 in translation).

[11-8225]

## STUDY OF A THIN-FILM LASER LOGIC GATE BASED ON RHODAMINE 6G

Kiev IZV. VUZ: RADIOELEKTRONIKA in Russian Vol 23, No 8, Aug 80 pp 70-76 manuscript received 4 Jun 79, after revision 11 Nov 79

DERYUGIN, L. N., KOLBIN, I. I., OVCHARENKO, O. I., CHEREMISKIN, I.V. and CHEKHLOVA, T. K.

[Abstract] Thin-film laser logic elements are analyzed theoretically and studied experimentally in order to determine their switching times and efficiencies. Kinetic equations are written for the response of a laser logic gate where a quenching signal is present from an identical gate. The relevant equations are solved in order to derive analytical expressions for the power and quenching characteristics. The experimental check used a pair of distributed feedback lasers employing rhodamine 6G, which have waveguide inputs and outputs. The material for the waveguide film was gelatin with the rhodamine 6G dissolved in it; the film was applied to a glass substrate. The distributed feedback was achieved by periodic variation of the waveguide thickness, which was in turn realized by making a diffraction grating in the substrate using photolithography in order to produce periodically arranged grooves with a period of 0.6 micrometers. The two mutually perpendicular thin-film laser logic gates were 2 x 2 mm, where the length of the quenching gate perpendicular to the lines of the grating varied from 0 to 3 mm. The device was pumped by the second harmonic of a neodymium LTIPCh-7 laser, polarized so that the vector was parallel to the axis of the laser gate being quenched and perpendicular to the axis of the quenching gate. A diaphragm varied the power of the quenching gate by changing the length of the active region. The radiation spectra of the gates were photographed and the spectrograms were processed with a microphotometer. The incident threshold pumping power for the quenched gate was 1.8 KW (the absorbed power was 130 W), and for the quenching gate it was 1.6 KW (an absorbed power of 120 W); the pumping intensities were 45 and 40 KW/cm<sup>2</sup> respectively. The quenching of the primary gate lasing was observed in a number of spectrograms and the results of photometry of these spectrograms showing the lasing power as a function of the variable length of the quenching gate are shown graphically. Complete quenching of both E and H modes was observed at a length of the gate perpendicular to the lines of the grating of 1.9 mm. The experimental values for the turn-on and turn-off times are 2.5 to 3.5 times greater than the calculated values, which is explained by the noninfinite slope of the trailing and leading edges of the quenching pulse. A comparison of such thin film laser gates with ECL circuits shows the following: 1) The speed of the laser gate is of the same order of magnitude as electronic logic components; and 2) Laser

gates with a supplemental resonator for the quenching signal, using stripline waveguides, are the most efficient; such elements can have power and dimensional characteristics comparable or better than the electronic counterparts. However, these devices are complex in terms of their structural design, require high precision in the fabrication and the development of a special technology is needed to produce them. Figures 5; references 9: 5 Russian, 4 Western (in translation). [11-8225]

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